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Forest Habitat Change Dynamics in a Riparian Wetland

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Abstract

Our study aims at monitoring ecosystem dynamics in the Szigetköz Danube floodplain (Hungary), where the wetland communities have been seriously affected by the abrupt hydrological changes after the Danube-diversion in 1992. Wetland habitats were mapped in the last years for a chosen area, based on a comparable use of archived analogue and digital aerial images and available silvicultural and botanical inventories. During the object-based image analysis the classification was mainly based on texture measures. The resulting map time series show habitat borders for each year and present the changes separately for each class. The method is suitable for the characterization of spatial and temporal structure of wetland land cover in a realistic way.

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Keywords: remote sensing; object based image analysis; wetland; change detection; aerial imagery; texture based classification.

1. Introduction

Wetlands are among the world's most productive ecosystems. Floodplain environments, in their natural state, have been cited to be of particular value since they have high biodiversity, provide critical habitats for many plants and animals and are an important, natural element in the maintenance of water quality [1]. During the last decades they have become the most vulnerable ecosystems, therefore the Ramsar Convention on Wetlands (1971) formulated the conservation and sustainable development strategy regarding wetlands, with national and international cooperation.

Monitoring of wetland areas is vital for an effective restoration management, where the application of remote sensing methods has a great potential, because it is non-invasive, cost-effective and time-efficient. In the image analysis the automated (computer-assisted) techniques, including pixel-based or object-

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based classifiers, are becoming more common in comparison to visual photo-interpretation or manual delineation [2]. Especially for high (or very high) resolution imagery the object-based method is applied more often, where the pixels are grouped into meaningful image objects, thereby the so-called “salt and pepper” effect is eliminated, which comes from the traditional classification methods. The object-based technique uses the information related to shape, site and spatial relation (context) of the objects, which is leading towards the incorporation and development of geographic-based intelligence in the image analysis [3]. The monitoring of changes can help us to understand the underlying biological processes, thus it is essential to achieve an accurate mapping method for the measurement of cover, complexity and habitat use [2].

The present study attempts to interpret riparian habitats and habitat changes in a Hungarian floodplain from aerial imagery, with the help of object based image analysis.

2. Study Site

The Hungarian Szigetköz floodplain together with the Slovakian Csallóköz is the most extended wetland in the Upper-Danube region with high biodiversity, which has suffered severe changes in 1992 with the Danube-diversion, leading approx. 80% of the water discharge into the bypass canal of the Gabčíkovo Hydropower Plant [4] [5]. From the whole Szigetköz region (37 500 ha) 9157 ha became landscape protected area in 1987, nowadays including NATURA 2000 SCI (sites of community interest), SPA (special protected areas) and IBA (important bird areas) and belongs to the Directorate of Fertő-Hanság National Park [6] . Because of the significant changes in the flow and sediment regime, the unique diverse pattern of habitat types has been changed from aquatic or aquatic-related forms to more terrestrial species, which means a decreasing biodiversity, in addition, with the increase of invasive species [7] .

3. Data

In order to lead a detailed investigation about the area, high resolution remote sensing data (aerial images) and ground truth information were gathered.

3.1 Aerial Imagery

The analysis of aerial images has a unique value for riparian ecosystem management, especially as a source of valuable historical information on vegetation cover and condition. In the most cases it is temporally continuous for a long time period (in some examples dating from the early 1930s) and thus ensures a spatially complete record of landscape changes [8]. There are several examples in literature, where the interpretation of high resolution aerial imagery was used for ecological studies (e.g. [8],[9], [10]).

Cserhalmi et al. [9] presented the analysis of black & white imagery for the reconstruction of mire vegetation change about a 50 years interval. In the research of Langanke et al. [10] the aim was to assess the mire conservation status of a raised bog in a similar time period, but they analysed different types of aerial photographs (black & white, colour infrared and true colour) with two interpretation techniques: a standard aerial photo-interpretation and a multi-scale object-based classification.

From our test site complete aerial coverage and orthophotos from the following years 2000, 2005, 2008 are available at the Institute of Geodesy, Cartography and Remote Sensing (FÖMI, Budapest), which were originally made for a detailed topographic mapping. The recent two examples (2005, 2008) were chosen for the presented study. Their data is summarized in *Table 1*.

Table 1.

Imagery	*Orthophoto 2005*	*Orthophoto 2008*
Scale of the aerial imagery	1:30 000	1: 74 000
Ground spatial resolution	0.5 m/pixel	0.5 m/pixel
Spectral resolution	RGB	CIR
Camera type	RC 20	UltraCamX
Acquisition time	2005.07.29.	2008.08.02-11.

3.2 Ancillary Data

In case of habitat mapping the collection of ground truth data cannot be ignored. Detailed botanical and silvicultural maps were collected (*Table 2*). The number of classes in each classification system is shown, respectively in brackets the number of classes for the actual map and for the sample site.

Table 2.

Ancillary Data	*Á-NÉR habitat map*	*Silvicultural map (Type of woodstand)*
No. of classes in the classification system	116, (14, 8)	101, (10, 3)
Scale	1:12 500	1:10 000
Acquisition time	2000, 2004 (July-October)	2003 (originally) – with recent actualisations

Regarding the botanical map the so-called Á-NÉR (general national habitat classifying system) is applied, which includes primarily the aspect of physiognomy and vegetation dynamics contrary to the forest categorisation, where the build-up of silvicultural species is more emphasized [11]. Personal field investigations were also carried out in 2010, November, which helps us in the comparison of images and additional maps to the real characteristics of vegetation.

Obviously there is a big challenge in the use of this information in the photo-interpretation, as the imagery and the field mapping were taken in different times.

The spatial availability of ground truth data (botanical maps of habitat types, silvicultural maps) defined the objective area of research, where the sample site around 180 000 m^2 was chosen.

4. Method: Interpretation of Aerial Imagery

Very high spatial resolution (VHR) imagery provides interesting data for forest inventory, where the application of object based analysis is reasonable [12]. Here through the information about spatial context, spatial statistics is involved in the image analysis. Thus there is a great potential to increase both the amount of information excluded from the imagery and the accuracy of interpretation in comparison to spectral approaches [13]. In the analysis procedure we can consider different characteristics of the imagery: tone or colour, size, shape, texture, pattern, shadow, local characteristics, landscape context and landscape position, which are often combined for good interpretation results [8]. Texture is one of the main context descriptors, which provides information about the spatial distribution of tonal variations within a band and their features are computed from angular nearest-neighbor gray-tone spatial-dependence matrices [14]. It was presented in several studies to be useful for landform and land-cover analysis, forest structural characteristics, prediction of species distribution and biodiversity patterns [8].

Laliberte & Rango [15][16] showed the capability of GLCM (gray level co-occurrence matrix) features for the improvement of classification accuracy during the analysis of high spatial resolution imagery.

Our objective during the interpretation was the integration of texture features into the improvement of segmentation results (image object fusion technique), into the classification and into the change detection process.

4.1 Segmentation & Classification

The object-based analysis was carried out in the eCognition Developer software environment (Version 8.64), which is the leader in this type of image processing in commercial use. Firstly we started our analysis with the 2008 orthophoto sample, since this type of image contains also the infrared band, which helps significantly in the class separation during the classification procedure.

The image sample was segmented after a trial & error process, ending in the application of quadtree and multiresolution algorithms, which gave the best results in order to have optimal borders between image objects.

Before starting to build the classification algorithms, classes had to be defined according to visual interpretation of imagery and ancillary data. Overlays between the 2005 year image (orthophoto) and the botanical and silvicultural maps have been made, so that it is possible to observe the different categories in the aerial photo. After visual observation 4 classes have been defined as objective classes during the analysis, namely: 1) water cover, 2) sedge, 3) mainly Populus species (human deployment) 4) mixture of Populus and Salix species. Here the categories of 1), 2) and 4) agree to the botanical classification, whilst category 3 has a different designation and there we apply the category from the forestry data.

In order to build relevant class descriptions, Haralick texture features are analysed. GLCM Correlation, Mean and Entropy were chosen for detailed investigations [17]. Texture feature values have to be examined for those objects, which are representative for a given class. In case of Water and Sedge Classes, image objects, came from the above mentioned segmentation method, have such texture measures which remain the same or similar for merged objects for the given classes. In contrary for Class 3 and 4 it is completely different. The reason is that those classes have low spectral homogeneity and the "candidate" image objects show big differences in the texture measures. For representative sample objects as input for the texture analysis, chessboard segmentation was applied for the scene, where those squares which were perfectly within an objective class, have been chosen as samples. After the texture and class-separation analysis with other features, class descriptions have been defined for the classes. GLCM Mean and Entropy have provided the best results in combination with other features in the class description.

For Water and Sedge Classes image objects were classified, whilst in case of Populus and Salix+Populus Classes image object fusion algorithm have been applied before the real classification with such conditions, that describe the behaviour of the merged image objects mainly based on the above mentioned texture features. After sufficient refinements we have reached an acceptable classification, where the producer's accuracy was 0.88, for the user's accuracy we have got 0.93.

4.2 Change Detection Analysis

In order to monitor recent alterations in habitats, change detection analysis has been developed for the sample site. Firstly we dealt with the earlier image (2005) separately. A general segmentation similar to the prior one has been carried out. After that in the classification process we observed the huge loss of NDVI for water detection because of the missing infrared channel, but it was possible to compare the segments with the image object boundaries and classes of the 2008 image.

In the software environment this means the use of different image object levels, where the existence of the 2008-classification for the 2005-image segments could have been analysed. With this technique we were able to eliminate numerous time-consuming refinement procedures concentrating on the earlier classified area and besides on its neighbourhood, where the change of a given habitat is potential.

Beyond the classification of water, where the brightness values and the existence-analysis assured sufficient information, texture features were examined and built into class descriptions for the remaining classes. After that the classification process was similar to the first analysis (year 2008) complemented with the possibilities of comparison.

We reached a sufficient classification result for the 2005 image, thus we have been able to analyse the change of the habitat borders during this time period (2005-2008) and in the end changed segments have been presented for each class.

5. Results

Object based image analysis has proved to be a suitable tool for the extraction of habitat information from CIR and RGB aerial imagery, where the appropriate use of various texture features has ensured promising results during the image object fusion and the classification procedure.

5.1 Classification of Habitat Types

It is fundamental that our analysis is based on aerial image interpretation supported by botanical and silvicultural data, where we have defined firstly those categories, which are potential classes for a semi-automatic image analysis. During the development of an image analysis procedure texture features were deeply involved and gave an acceptable classification result. Habitat classification for the RGB imagery was also acceptable where the comparative technique to the prior classification of CIR imagery had a significant role.

5.2 Detection of Changes

During the change detection methodology comparison to prior classifications helps us detecting accurately the changes of each habitat polygon. The classification of the antecedent image became easier in the way that complex refinement techniques for the categorisation could be left out.

We established that different water coverage characterized the year 2005 and 2008, which has shown distinct hydrological conditions, although the image acquisition time (day) in the given years was almost the same *(Table 1)*. In case of Class Sedge, we detected those areas which were lost as sedge during these 3 years. For Class Populus we could delineate one significant part which didn’t belong to the Class in 2005.

6. Conclusion & Outlook

Habitat mapping has well accepted approaches, however, during the production of habitat maps questions often occur regarding the definition of a habitat in terms of measurable variables [18]. It leads us directly to the botanical aspect, which should be investigated during the image interpretation. Due to the lack of high resolution ground truth data in space and time an accurate delineation remains a challenging task, however, the improvement of delineation’s accuracy is an objective of further researches. The extension of the test site is also an important issue for future experiments.

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